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# An Energy Forecasting and Analysis System for the U.S. Army Materiel Command

by
Michael J. Binder

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Direct comparison of current and base fiscal year energy consumption data is not a satisfactory method for evaluating energy conservation measures, as the effectiveness of these efforts may easily appear enhanced or diminished due to differences in weather and level of production between the current and base fiscal years. For a realistic assessment, energy managers need a mathematically sound methodology to "filter out" the effects caused by year-to-year differences in weather and production levels.

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## FOREWORD

This work was performed for the U. S. Army Engineering and Housing Support Center (USAEHSC) under Project 4A162781AT45, "Energy and Energy Conservation"; Task B, "Installation Energy Conservation"; Work Unit 012, "AMC Energy System Modernization." Mr. B. Wasserman, CEHSC-FU, was the USAEHSC Technical Monitor.

The work was performed by the Energy Systems Division (ES) of the U. S. Army Construction Engineering Research Laboratory (USACERL). Dr. G. R. Williamson is Chief, ES. The USACERL technical editor was Dana Finney, Information Management Office.

The EFAS System was programmed in Microsoft Quick BASIC by David T. McKay. Enhancements were made by Jeffery Morton. Appreciation for their efforts is expressed to both.

COL Carl O. Magnell is Commander and Director of USACERL, and Dr. L. R. Shaffer is Technical Director.

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# 1 INTRODUCTION

## Background

The Army has been assigned energy reduction goals with a base year of FY85 and a target year of FY95. These goals call for (1) an 8 percent reduction in existing building energy consumption (Btu per square foot) and (2) a 10 percent reduction in industrial process energy intensity (Btu/productivity indicator). Industrial process energy is defined as "the facilities energy utilized in the direct production or rehabilitation of equipment or goods".[1] Any other type of facilities energy consumption (and industrial process energy consumption where appropriate productivity indicators cannot be identified), is to be considered building energy and managed on a Btu per square foot basis.

To meet these goals, energy managers are tasked with identifying potential energy conservation opportunities and implementing those which prove cost-effective. They also are required to assess the effectiveness of energy conservation efforts in terms of progress toward achieving energy consumption reduction goals.

Direct comparison of energy consumption data for the current fiscal year with the base year data is not a satisfactory method for evaluating energy conservation efforts because it does not account for differences in weather and production levels between the two fiscal years. As a result, the effectiveness of an organization's conservation measures may appear enhanced or diminished with respect to actual performance. This type of result would not affect industrial process energy management at installations that have defined appropriate productivity indicators, because the separate management of this energy on the basis of Btu per productivity indicator would account for differences in production levels. Also, it could be assumed that industrial process energy consumption is not directly responsive to variations in weather data. However, it is very difficult to identify appropriate productivity indicators and this has been done successfully in only a very limited number of cases. For the most part, differences in production levels between current and base fiscal years make direct comparison of energy consumption data ineffectual. In all cases, differences in weather data between current and base fiscal years prevent a realistic assessment of conservation efforts using such a direct comparison.

To make valid assessments, energy managers require a mathematically sound methodology to "filter out" the effects caused by year-to-year differences in weather and production levels. Such a method would allow managers to make comparisons between energy consumption patterns as opposed to actual energy consumption data. Previous studies have shown the statistical technique of multiple regression analysis to be an effective tool for characterizing energy consumption patterns involving variations

[1] Department of Defense, Defense Energy Program Policy Memorandum (DEPPM) 86-3, (16 April 1986).

in weather and production levels.[2] Based on these findings, the U. S. Army Materiel Command (AMC) asked the U. S. Army Construction Engineering Research Laboratory (USACERL) to develop a computer system that would use multiple regression analysis for energy management at the Major Command (MACOM) level.

## Objective

The objective of this study was to develop an automated Energy Forecasting and Analysis System (EFAS) based on multiple regression analysis that would allow MACOM-level energy managers to (1) establish annual energy consumption goals for individual installations and Major Subordinate Commands (MSCs) and (2) assess progress toward attaining energy reduction goals based on energy consumption patterns.

## Approach

Energy consumption, heating degree days (HDD), cooling degree days (CDD), and labor force (LBRFRC) data were gathered from 59 AMC installations. Multiple regression analysis was used to determine which of the three potential independent variables (HDD, CDD, LBRFRC) were significant at each installation. The AMC data comprise the EFAS database, which was developed using BASIC programming language. The EFAS software is designed to allow managers to (1) update regression equations as new data become available, (2) estimate initial and adjusted energy consumption and compare these values with actual consumption on monthly, quarterly, and annual bases, and (3) automatically generate the results for an individual installation, individual MSC, or for the entire AMC.

## Mode of Technology Transfer

EFAS is being used by the AMC Headquarters Energy Office. The regression analysis concept and glide path adjustment method described in this report could be adapted for effective energy management strategies at other MACOMs.

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[2] B. Sliwinski and E. Elischer, *Analysis of Facilities' Energy Use Patterns*, Technical Report E-186/ADA132527 (U.S. Army Construction Engineering Research Laboratory [USACERL], 1983); B. Sliwinski, *A Model of U.S. Army Materiel Command (AMC) Energy Consumption, Volume I: Development of Monthly Energy Consumption Equations*, Technical Report E-86/02/ADA167366 (USACERL, 1986).

## 2 SUMMARY OF THE MULTIPLE REGRESSION TECHNIQUE

The multiple regression technique allows a quantitative analysis of the relationship between a "dependent" variable (to be predicted or explained) and one or more "independent" variables (changes to which the dependent variable is responsive). This technique produces a mathematical expression, called a "regression equation," that predicts the value of the dependent variable by knowing the values of the independent variables. It also provides statistics that quantify the explanatory power of the regression equation, the expected errors of this equation, and the statistical significance of each independent variable.

Consider the case in which a dependent variable Y is assumed to be a linear function of only one independent variable X. The extension to more than one independent variable, while more complex mathematically, is identical in concept to the simpler one-independent-variable case. The linear relationship between Y and X may be expressed as:

$$Y_p = B_0 + B_1 \cdot X \qquad \text{[Eq 1]}$$

where:

$Y_p$ = predicted value of Y

$B_0, B_1$ = parameters whose values are to be determined by multiple regression analysis.

For each value of X, ($X_i$), there will be an associated predicted value of Y, ($Y_{Pi}$), and an associated actual value of Y, ($Y_i$). The error ($e_i$) is defined as the difference between the actual and predicted values:

$$e_i = Y_i - Y_{Pi} \qquad \text{[Eq 2]}$$

Multiple regression analysis determines values for the parameters $B_0$ and $B_1$ in a way that minimizes the sum of the squares of the errors ($\Sigma\ e_i^2$).

As a first step in the regression analysis, $B_1$ can be set equal to zero and $B_0$ set equal to the mean value of Y, ($Y_M$), over the data range considered (i.e., $Y_{Pi} = Y_M$ for all $X_i$). The resulting errors can be calculated ($e_i = Y_i - Y_M$), squared, and summed over all the values of $Y_i$, producing a value called the "Sum of Squares About the Mean" (SS about mean). The next step in regression analysis is to determine values for both $B_0$ and $B_1$ in such a way as to minimize the sum of the squares of the errors (SS error). The difference between (SS about mean) and (SS error) is called the "Sum of Squares Due to Regression" (SS due to regression):

$$\text{(SS due to regression)} = \text{(SS about mean)} - \text{(SS error)} \qquad \text{[Eq 3]}$$

The ratio of (SS due to regression) to (SS about mean) is called the "Correlation Coefficient" ($R^2$):

$$R^2 = (\text{SS due to regression}) / (\text{SS about mean}) \quad \text{[Eq 4]}$$

Thus, $R^2$ represents the percentage of variance of the dependent variable which is explained by the variance of the independent variables. The closer the value $R^2$ is to unity, the better the predictive ability of the regression equation. The Mean Square Error (MS error) is defined as:

$$(\text{MS error}) = (\text{SS error}) / (n - q) \quad \text{[Eq 5]}$$

where: $n$ = number of data points

$q$ = number of parameters to be determined by regression analysis (e.g., $q = 2$ for the case of one independent variable).

The Standard Error ($\sigma$) is defined as the square root of (MS error):

$$\sigma = \sqrt{(\text{MS error})} \quad \text{[Eq 6]}$$

Equations 5 and 6 indicate that, in order to *minimize error, the multiple regression* analysis should be performed using the largest number of data points and the least number of independent variables possible consistent with obtaining a reasonable value of $R^2$.

# 3 DEVELOPMENT OF EFAS

## Previous Studies

In a study of facilities energy use patterns,[3] multiple regression analysis was used to analyze hourly energy consumption data taken between 1976 and 1979 for 70 buildings at Fort Carson, CO, Fort Hood, TX, and Fort Belvoir, VA. The results of the study indicated that multiple regression analysis could be used to provide reasonable estimates of energy consumption for aggregates of 10 or more buildings based on HDD, CDD, and building square footage by building type. Building type classifications used in the study included family housing, troop housing, and administration/training, dining, medical/dental, product maintenance, community, and storage facilities.

Multiple regression analysis was also used in developing equations to relate energy consumption to weather and process parameters on a monthly basis for the Armament Munitions and Chemical Command (AMCCOM), and on a quarterly basis for the Depot Systems Command (DESCOM).[4] AMCCOM and DESCOM are MSCs of AMC. Regression equations were developed for 23 AMCCOM and 11 DESCOM installations. The regression equations for AMCCOM installations were based on data for the range FY75 to FY82, whereas those for DESCOM installations were based on the data range FY75 to FY83. Results of the analysis indicated that HDD was a significant independent variable at all installations. CDD was found to be a significant variable at only a very few installations, all located in hot climates. The only process parameter found to provide significant increases in the correlation coefficient when entered into the monthly regression equations was the contractor labor force (LBRFRC). This parameter was significant for about 50 percent of the AMCCOM installations. Attempts to develop regression equations for DESCOM installations on a monthly basis met with only very limited success.

## Incentives for Developing EFAS

The regression equations developed for AMCCOM and DESCOM installations were used by the AMC Headquarters (HQ) Energy Office during FY84 and FY85 to assess the effectiveness of energy conservation efforts at those installations for which suitable equations had been developed. Calculations during this period were performed manually and data storage was by hard copy. The initial incentive for developing EFAS was to eliminate these sources of inefficiency by automating the calculations and data manipulation associated with using the equations and by providing magnetic media storage.

The AMC HQ Energy Office also asked that the monthly energy consumption regression equations be expanded to include all AMCCOM and DESCOM installations as well as those in the other seven AMC MSCs. These MSCs include the Aviations Systems Command (AVSCOM), Communications/Electronics Command (CECOM), Laboratory Command (LABCOM), Missile Command (MICOM), Tank - Automotive Command (TACOM), Test and Evaluation Command (TECOM), and Troop Support Command (TROSCOM). The initial system requirements called for comparisons of actual energy consumption with estimated energy consumption as given by the regression equations, presented on monthly, quarterly, and annual bases for individual installations, individual MSCs, or all of AMC. These incentives and system requirements formed the driving

[3] B. Sliwinski and E. Elischer.
[4] B. Sliwinski.

force for the early stages of EFAS development. Other factors that influenced the research effort and contributed to the capabilities of the final product are discussed in the rest of this chapter.

**Change in the Electrical Energy Consumption Conversion Factor**

The event having the largest impact on EFAS development was a Department of Defense (DOD) policy change that became effective in FY86.[5] This directive changed the "source" conversion factor (11,600 Btu/kWh)* to the "site" conversion factor (3413 Btu/kWh) for electrical energy consumption reporting to the Defense Energy Information System (DEIS). Since all regression equations developed to date had been based on historical total energy consumption data calculated using the "source" conversion factor, this change rendered them invalid. This situation required USACERL to retrieve the original electrical consumption data reported in kWh, convert these data to MBtu using the "site" conversion factor, and sum over all of the various types of energy consumption to obtain new energy consumption totals. Regression analysis was then performed on the new total energy consumption data and new regression equations were developed. These new equations showed an increased significance of the HDD variable and decreased significance of the CDD and LBRFRC variables. In some cases, CDD and/or LBRFRC did not appear in the new regression equations, whereas they had appeared in the equations based on "source" conversion energy consumption totals.

Despite the negative impact this change had on EFAS development, it also produced some benefits. Total facilities energy consumption generally includes electrical energy consumption and heating fuel consumption (e.g., natural gas). Heating fuel consumption is well correlated with HDD and usually does not exhibit uncorrelated steady increases with time. Hence, conservation efforts in the area of heating fuel consumption are fully reflected as decreases in total energy consumption pattern. Electrical energy consumption, however, does normally exhibit uncorrelated steady increases with time due to events such as increased use of computer equipment and the associated temperature and humidity control requirements and, in Army industrial facilities, the trend to use energy-intensive production equipment to replace manual labor (e.g., robotics) for economy. Conservation efforts in the area of electrical energy consumption may therefore be masked or even overshadowed by these uncorrelated increases with time, and may not be reflected as decreases in the total energy consumption pattern. The change to the "site" conversion factor has deemphasized electrical energy consumption and increased the emphasis of heating fuel consumption in the determination of total energy consumption. From an energy management standpoint, this shift makes it easier to attain energy reduction goals since changes in heating fuel consumption would now be reflected as larger changes in total energy consumption, and changes in electrical energy consumption would now be reflected as smaller changes in total energy consumption on a percentage basis.

The change to the "site" conversion factor also had the effect of improving the accuracy of the new equations and, in some cases, allowed USACERL to develop suitable equations where none had been possible previously. The latter result was due to the fact that regression equations developed from highly correlated data (e.g., for heating fuel) exhibit high values of correlation coefficient, whereas those developed from data having uncorrelated variations with time (e.g., electrical energy) exhibit much lower values of

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[5]DEPPM 86-3.
*1 Btu = 1.055 kJ.

correlation coefficient. Since total energy consumption is calculated by summing both the highly correlated heating fuel consumption and the poorly correlated electrical energy consumption, the accuracy of regression equations developed for total energy consumption depends on the relative contributions made by heating fuel and electrical energy to the total value. The change to the "site" conversion factor increased the relative contribution of heating fuel to the total consumption, thus increasing the fraction of total energy consumption that was highly correlated with HDD and producing values of correlation coefficient which were much higher than those obtained with the "source" factor.

**Problems Associated With Fixed Database Regression Analysis**

The equations that had been developed previously for AMCCOM installations were based on data for the range FY75 to FY82, whereas those developed for DESCOM installations covered the data range FY75 to FY83. All data within these respective ranges were used in the regression analyses. This approach works well, provided changes in consumption pattern are relatively minor throughout the data range. If so, then this approach is preferred since, as was noted in Chapter 2, accuracy of the equation is increased by using the largest number of data points possible consistent with obtaining reasonable values of $R^2$. However, that was not the case for several installations, and the regression equations obtained for them exhibited low values of correlation coefficient.

A particular case in point is that of the Volunteer Army Ammunition Plant (AAP). Figure 1* is a graph of contractor LBRFRC at Volunteer AAP as a function of time over the FY75 to FY82 data range. It is seen that the contractor LBRFRC decreased considerably over this data range. In fact, Volunteer AAP went from an active to an inactive status during this time period. The regression equation obtained based on the entire data range had a very low correlation coefficient. A far more accurate equation would have been obtained had the data range used in the analysis been limited to a time period over which only minor changes in consumption pattern occurred, such as the range FY80 to FY82. EFAS was therefore developed to allow the data range used in the regression analysis to vary in such a way that the resulting regression equation is based on the data range producing the maximum value of $R^2$. Chapter 4 contains a detailed description of the algorithm by which this step is done.

As noted earlier, the AMC HQ Energy Office used the old equations during FY84 and FY85 to assess the effectiveness of energy conservation measures. Presumably, the equations would have continued to be used for energy management had they not been rendered invalid by the change to the "site" conversion factor for electrical energy consumption. The use of equations that characterize FY82 (for AMCCOM installations) or FY83 (for DESCOM installations) consumption patterns for predicting energy usage in all subsequent years would be practical only if no changes in energy consumption patterns were anticipated. Since the driving force behind EFAS development was to provide energy managers a tool with which they could assess the effectiveness of energy conservation efforts toward attaining the Army's energy goals, it is clear that significant changes in energy consumption patterns with time must be anticipated. Therefore, the utility of fixed database regression equations would decrease from year to year. The disparity between these equations and actual energy consumption patterns could be quite considerable by the time the target year FY95 is reached. This reasoning led to the

*Figures and tables are located at the end of each chapter.

requirement that EFAS provide the ability to update the installation regression equations as new data become available. Details on updating the regression equations are presented in Chapter 4.

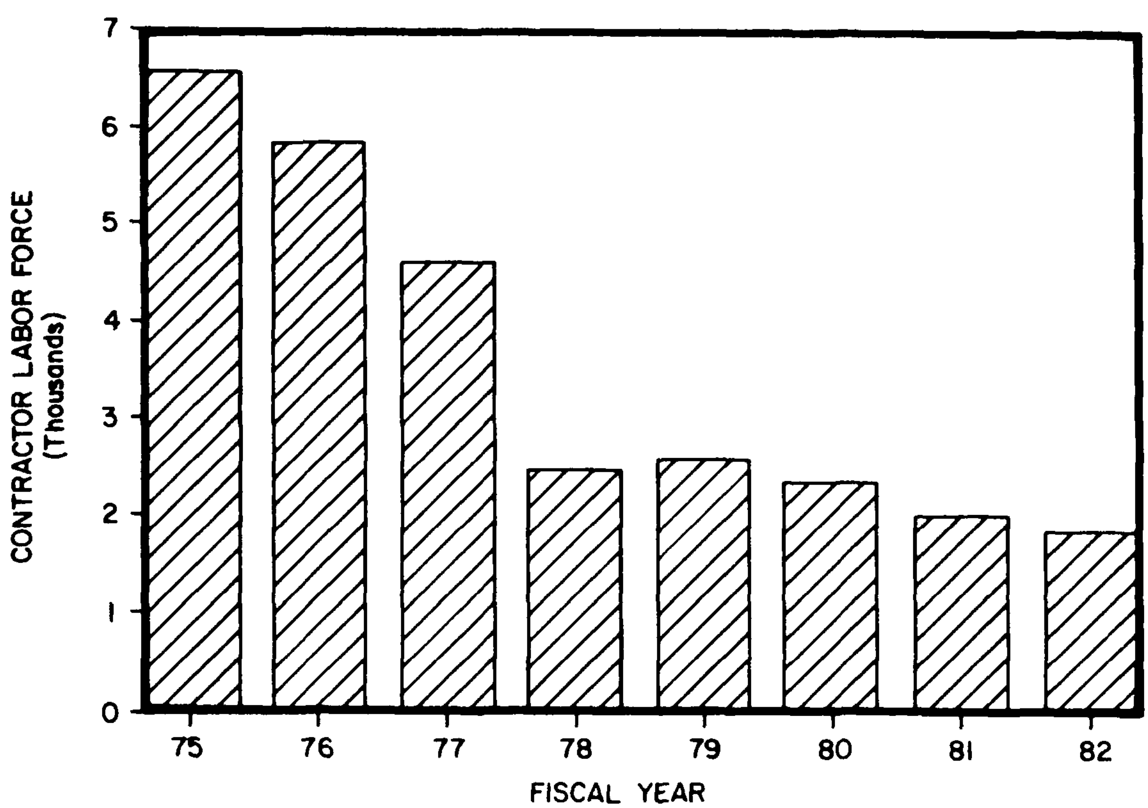


**Figure 1. Contractor labor force variation at Volunteer AAP.**

# 4 EFAS DATABASE AND FEATURES

## Database

The EFAS database, as provided to the user, contains pertinent monthly data for 59 AMC installations from FY75 to FY86. For convenience, the 59 installations are grouped into four categories: AMCCOM, DESCOM, TECOM, and Other Installations. In all cases, total facilities energy consumption (MBtu) and HDD data are provided. In addition, CDD and/or LBRFRC data are included for installations where these independent variables have been determined to be significant.

DEIS facilities energy consumption and LBRFRC data were supplied by AMC HQ. Weather data (HDD, CDD) were obtained from National Oceanic and Atmospheric Administration (NOAA) weather stations located near the individual installations. Tables 1 through 4 list the installations and their associated weather station locations for AMCCOM, DESCOM, TECOM, and Other Installations, respectively. The database can be updated manually using an EFAS option or, with the exception of LBRFRC, can be downloaded from the Army DEIS Data Entry System (ADDS) by means of an ADDS/EFAS interface supplied with EFAS.

Also included in the EFAS database are sets of equations obtained by multiple regression analysis which characterize the energy consumption patterns at a given installation for given fiscal years. The data range on which a particular equation is based extends from some starting fiscal year through the end of the fiscal year for which the equation represents the energy consumption pattern. The method by which the starting fiscal year is determined is discussed below under **Updating the Regression Equations.** Equations that characterize the energy consumption pattern for a given fiscal year are used to predict energy consumption for the following fiscal year (e.g., the equation used to predict energy consumption for FY87 is based on a data range through FY86). All regression equations contained in the EFAS database are of the general form:

$$\mathrm{MBtu} = B_0 + B_1 \cdot \mathrm{HDD} + B_2 \cdot \mathrm{CDD} + B_3 \cdot \mathrm{LBRFRC} \qquad \text{[Eq 7]}$$

In many cases, the coefficients $B_2$ and/or $B_3$ are equal to zero, indicating that CDD and/or LBRFRC were not found to be significant independent variables at that installation. Prediction equations for FY86 (based on data through FY85), the associated values of $R^2$, and the data range on which each equation is based are given in Tables 5 through 8 for AMCCOM, DESCOM, TECOM, and Other Installations, respectively. The equivalent information for FY87 (based on data through FY86) is given in Tables 9 through 12. Prediction equations for any given fiscal year are stored in the EFAS database to allow for comparisons of energy consumption patterns from year to year.

## Updating the Regression Equations

EFAS has an option for calculating new regression equations. These new equations are calculated automatically when this option is chosen if additional data constituting a full fiscal year have been added to the database. Existing regression equations can also be recalculated for a given fiscal year if necessary. This would be the case if pertinent data were edited after the regression equation had been calculated. The regression equation and the associated value of $R^2$ for a particular installation and fiscal year are

initially determined based on the data range FY75 to the fiscal year of interest. The first 12 data points (corresponding to FY75) are then discarded and another regression equation and associated value of $R^2$ are calculated based on the abbreviated data range (FY76 to the fiscal year of interest). The data corresponding to FY76 are then discarded and another regression equation and associated value of $R^2$ determined based on the data range FY77 to the fiscal year of interest. This process of discarding data for the least recent fiscal year and recalculating the regression equation and associated value of $R^2$ continues until the abbreviated database contains only the most recent 3 years of data (the fiscal year of interest and the two previous fiscal years).

Next, the values of $R^2$ for the set of equations thus generated are compared, and the equation corresponding to the largest value of $R^2$ is entered into the database for use in predicting energy consumption for the following fiscal year. The value of $R^2$ and the data range associated with this equation are also stored in the database. The requirement that the regression equation be based on at least 3 years' data was added to EFAS to minimize the standard error. The fact that the associated data range always includes the most recent data allows the regression equations to account for changes in energy consumption patterns over time. It should be noted, however, that a time lag of 1 to 3 years will occur before the regression equations will be able to adequately account for drastic changes in energy consumption patterns.

## EFAS Output

EFAS output consists of initial energy consumption predictions or "goals," adjusted energy consumption goals, and the percentage difference between adjusted energy consumption goals and actual energy consumption for any given fiscal year. Output is available for individual installations, individual MSCs, and all of AMC on monthly, quarterly, and annual bases.

Results of installation regression equations for which the associated values of $R^2$ are less than 0.5 are not included in MSC and AMC summary reports. Initial energy consumption goals are determined using 30-year average weather data and projected contractor LBRFRC data in the regression equations. Projected contractor LBRFRC values for any given month are initially set equal to the average LBRFRC values for the corresponding fiscal quarter of the preceding fiscal year for the particular installation. These values can be edited as contractor-supplied LBRFRC projections become available. Adjusted energy consumption goals are calculated by using actual weather and LBRFRC data in the regression equations as they become available.

Ta... 1

**NOAA Weather Station Locations—AMCCOM Installations**

| Installation | Weather Station |
| --- | --- |
| Badger AAP* | Madison, WI |
| Cornhusker AAP | Grand Island, NB |
| Hawthorne AAP | Bishop, CA |
| Holston AAP | Bristol, TN |
| Indiana AAP | Louisville, KY |
| Iowa AAP | Peoria, IL |
| Joliet AAP | Chicago (O'Hare), IL |
| Kansas AAP | Wichita, KS |
| Lake City AAP | Kansas City, MO |
| Lone Star AAP | Shreveport, LA |
| Longhorn AAP | Shreveport, LA |
| Louisiana AAP | Shreveport, LA |
| McAlester AAP | Tulsa, OK |
| Milan AAP | Memphis, TN |
| Mississippi AAP | New Orleans, LA |
| Newport AAP | Indianapolis, IN |
| Picatinny Arsenal | Newark, NJ |
| Pine Bluff Arsenal | Little Rock, AR |
| Radford AAP | Roanoke, VA |
| Ravenna AAP | Akron, OH |
| Riverbank AAP | Stockton, CA |
| Rock Island Arsenal | Moline, IL |
| Rocky Mountain Arsenal | Denver, CO |
| Scranton AAP | Scranton, PA |
| Sunflower AAP | Kansas City, MO |
| Twin Cities AAP | Minneapolis-St. Paul, MN |
| Volunteer AAP | Chattanooga, TN |
| Watervliet Arsenal | Albany, NY |

*AAP = Army Ammunition Plant.

Table 2

NOAA Weather Station Locations—DESCOM Installations

| Installation | Weather Station |
|---|---|
| Anniston AD* | Birmingham, AL |
| Corpus Christi AD | Corpus Christi, TX |
| Fort Wingate DA** | Albuquerque, NM |
| Letterkenny AD | Harrisburg, PA |
| Lexington-Bluegrass AD | Lexington, KY |
| New Cumberland AD | Harrisburg, PA |
| Pueblo DA | Pueblo, CO |
| Red River AD | Shreveport, LA |
| Sacramento AD | Sacramento, CA |
| Savanna DA | Moline, IL |
| Seneca AD | Syracuse, NY |
| Sharpe AD | Stockton, CA |
| Sierra AD | Reno, NV |
| Tobyhanna AD | Scranton, PA |
| Tooele AD | Salt Lake City, UT |
| Umatilla DA | Pendleton, OR |

*AD = Army Depot.
**DA = Depot Activity.

Table 3

NOAA Weather Station Locations—TECOM Installations

| Installation | Weather Station |
|---|---|
| Aberdeen PG* | Baltimore, MD |
| Dugway PG | Salt Lake City, UT |
| Jefferson PG | Indianapolis, IN |
| White Sands MR** | Roswell, NM |
| Yuma PG | Yuma, AZ |

*PG = Proving Ground.
**MR = Missile Range.

## Table 4

### NOAA Weather Station Locations—Other Installations

| Installation | Weather Station |
|---|---|
| Detroit Arsenal | Detroit, MI |
| Fort Monmouth | Newark, NJ |
| Harry Diamond Labs | Washington, DC |
| Lima Army Tank Plant | Dayton, OH |
| Materials Technology Lab | Boston, MA |
| Natick RD&E Center | Boston, MA |
| Pontiac Storage Activity | Detroit, MI |
| Redstone Arsenal | Huntsville, AL |
| St. Louis Area Support Center | St. Louis, MO |
| Stratford Army Engine Plant | Bridgeport, CT |

## Table 5

### EFAS FY86 Regression Equations—AMCCOM Installations

General Equation: $MBtu = B_0 + B_1 \cdot HDD + B_2 \cdot CDD + B_3 \cdot LBRFRC$

| Installation | $B_0$ | $B_1$ | $B_2$ | $B_3$ | $R^2$ | FY Range |
|---|---|---|---|---|---|---|
| Badger AAP* | 885.52 | 7.37 | 0 | -0.69 | 0.9073 | 83-85 |
| Cornhusker AAP | 255.09 | 4.14 | 0 | 0 | 0.6777 | 75-85 |
| Hawthorne AAP | 5004.66 | 44.42 | 0 | 0 | 0.8601 | 83-85 |
| Holston AAP | -85618.75 | 90.43 | 0 | 318.11 | 0.8665 | 83-85 |
| Indiana AAP | 4340.60 | 37.45 | 0 | 0 | 0.9281 | 82-85 |
| Iowa AAP | 20395.53 | 90.56 | 0 | 0 | 0.9572 | 83-85 |
| Joliet AAP | -95797.80 | 27.72 | 0 | 334.62 | 0.8932 | 76-85 |
| Kansas AAP | 4012.58 | 19.44 | 0 | 0 | 0.9152 | 79-85 |
| Lake City AAP | 25611.92 | 54.00 | 0 | 13.16 | 0.8867 | 80-85 |
| Lone Star AAP | 36362.28 | 81.25 | 0 | 0 | 0.8442 | 83-85 |
| Longhorn AAP | 18912.25 | 39.39 | 0 | 16.56 | 0.8560 | 80-85 |
| Louisiana AAP | -18445.21 | 47.01 | 0 | 42.63 | 0.8423 | 77-85 |
| McAlester AAP | 7460.96 | 50.65 | 0 | 0 | 0.8454 | 75-85 |
| Milan AAP | 8579.67 | 48.61 | 0 | 0 | 0.9377 | 80-85 |
| Mississippi AAP | 19611.56 | 4.17 | 0 | 0 | 0.0011 | 82-85 |
| Newport AAP | 1740.64 | 12.57 | 0 | 0 | 0.9516 | 83-85 |
| Picatinny Arsenal | 74923.40 | 106.43 | 0 | 0 | 0.8796 | 83-85 |
| Pine Bluff Arsenal | 27217.08 | 43.76 | 0 | 0 | 0.7351 | 83-85 |
| Radford AAP | -137455.20 | 185.38 | 0 | 142.66 | 0.8194 | 75-85 |
| Ravenna AAP | -1085.04 | 9.73 | 0 | 15.08 | 0.8847 | 83-85 |
| Riverbank AAP | 9462.42 | -2.90 | 0 | 0 | 0.0222 | 83-85 |
| Rock Island Arsenal | 51275.55 | 70.28 | 0 | 0 | 0.9554 | 82-85 |
| Rocky Mountain Arsenal | 10666.94 | 33.68 | 0 | 0 | 0.7926 | 83-85 |
| Scranton AAP | 32867.99 | 22.45 | 0 | 0 | 0.6811 | 83-85 |
| Sunflower AAP | -135085.80 | 41.97 | 0 | 309.45 | 0.7998 | 82-85 |
| Twin Cities AAP | 10853.61 | 37.21 | 0 | 82.88 | 0.9364 | 75-85 |
| Volunteer AAP | 1583.90 | 1.31 | 0 | -3.01 | 0.9174 | 83-85 |
| Watervliet Arsenal | 20713.55 | 42.44 | 0 | 0 | 0.9459 | 81-85 |

*AAP = Army Ammunition Plant.

## Table 6

## EFAS FY86 Regression Equations—DESCOM Installations

General Equation: $MBtu = B_0 + B_1 \cdot HDD + B_2 \cdot CDD + B_3 \cdot LBRFRC$

| Installation | $B_0$ | $B_1$ | $B_2$ | $B_3$ | $R^2$ | FY Range |
|---|---|---|---|---|---|---|
| Anniston AD* | 34719.12 | 74.82 | 0 | 0 | 0.9241 | 83-85 |
| Corpus Christi AD | 36052.38 | 42.92 | 9.58 | 0 | 0.2435 | 83-85 |
| Fort Wingate DA** | 498.57 | 2.98 | 0 | 0 | 0.7208 | 83-85 |
| Letterkenny AD | 24338.51 | 49.77 | 9.03 | 0 | 0.8732 | 81-85 |
| Lexington-Bluegrass AD | -321.98 | 35.87 | 0 | 4.96 | 0.8786 | 81-85 |
| New Cumberland AD | 14440.52 | 55.07 | 0 | 0 | 0.9504 | 81-85 |
| Pueblo DA | 7568.77 | 22.67 | 0 | 0 | 0.8734 | 83-85 |
| Red River AD | -79309.78 | 89.36 | 0 | 20.30 | 0.9088 | 82-85 |
| Sacramento AD | 11988.74 | 28.31 | 0 | 0 | 0.6594 | 83-85 |
| Savanna DA | 731.79 | 16.99 | 0 | 0 | 0.9748 | 82-85 |
| Seneca AD | 4473.86 | 18.57 | 0 | 0 | 0.9626 | 82-85 |
| Sharpe AD | 8774.43 | 9.63 | 0 | -3.98 | 0.9226 | 83-85 |
| Sierra AD | 3969.54 | 14.69 | 0 | 0 | 0.8886 | 81-85 |
| Tobyhanna AD | 16325.43 | 63.66 | 0 | 0 | 0.9343 | 81-85 |
| Tooele AD | 21222.83 | 57.37 | 0 | 0 | 0.8671 | 81-85 |
| Umatilla DA | 181.62 | 6.38 | 0 | 0 | 0.6431 | 81-85 |

*AD = Army Depot.
**DA = Depot Activity.

## Table 7

## EFAS FY86 Regression Equations—TECOM Installations

General Equation: $MBtu = B_0 + B_1 \cdot HDD + B_2 \cdot CDD + B_3 \cdot LBRFRC$

| Installation | $B_0$ | $B_1$ | $B_2$ | $B_3$ | $R^2$ | FY Range |
|---|---|---|---|---|---|---|
| Aberdeen PG* | 109024.70 | 260.53 | 0 | 0 | 0.9669 | 83-85 |
| Dugway PG | 17831.27 | 21.39 | 0 | 0 | 0.6019 | 81-85 |
| Jefferson PG | 3569.36 | 6.73 | -3.20 | 0 | 0.6925 | 81-85 |
| White Sands MR** | 38196.00 | 63.37 | 0 | 0 | 0.9364 | 83-85 |
| Yuma PG | 7857.69 | 14.44 | 6.44 | 0 | 0.3204 | 83-85 |

*PG = Proving Ground.
**MR = Missile Range.

## Table 8

## EFAS FY86 Regression Equations—Other Installations

General Equation: $MBtu = B_0 + B_1 \cdot HDD + B_2 \cdot CDD + B_3 \cdot LBRFRC$

| Installation | $B_0$ | $B_1$ | $B_2$ | $B_3$ | $R^2$ | FY Range |
|---|---|---|---|---|---|---|
| Detroit Arsenal | 31894.17 | 61.79 | 0 | 0 | 0.8720 | 83-85 |
| Fort Monmouth | 41597.07 | 94.13 | 0 | 0 | 0.9146 | 83-85 |
| Harry Diamond Labs | 16890.95 | 11.89 | 0 | 0 | 0.8903 | 83-85 |
| Lima Army Tank Plant | -39839.96 | 33.33 | 0 | 20.30 | 0.8894 | 83-85 |
| Materials Technology Lab | 3241.77 | 16.15 | 0 | 0 | 0.8174 | 83-85 |
| Natick RD&E Center | 9016.26 | 7.15 | 0 | 0 | 0.8470 | 83-85 |
| Pontiac Storage Activity | 251.64 | -1.81 | 0 | 0 | 0.0029 | 82-85 |
| Redstone Arsenal | 66459.80 | 211.51 | 0 | 0 | 0.8045 | 81-85 |
| St. Louis Area Support Center | 5710.92 | 22.60 | 0 | 0 | 0.7324 | 83-85 |
| Stratford Army Engine Plant | 49463.45 | 29.16 | 0 | 0 | 0.3596 | 81-85 |

## Table 9

## EFAS FY87 Regression Equations—AMCCOM Installations

General Equation: $MBtu = B_0 + B_1 \cdot HDD + B_2 \cdot CDD + B_3 \cdot LBRFRC$

| Installation | $B_0$ | $B_1$ | $B_2$ | $B_3$ | $R^2$ | FY Range |
|---|---|---|---|---|---|---|
| Badger AAP* | -598.16 | 6.50 | 0 | 3.83 | 0.8565 | 84-86 |
| Cornhusker AAP | 83.96 | 2.77 | 0 | 0 | 0.8673 | 84-86 |
| Hawthorne AAP | 4191.48 | 41.99 | 0 | 0 | 0.8297 | 83-86 |
| Holston AAP | -79853.47 | 85.65 | 0 | 315.13 | 0.8485 | 83-86 |
| Indiana AAP | 3825.19 | 34.50 | 0 | 0 | 0.9597 | 84-86 |
| Iowa AAP | 21132.66 | 85.66 | 0 | 0 | 0.9560 | 84-86 |
| Joliet AAP | -93673.16 | 27.28 | 0 | 331.00 | 0.8892 | 76-86 |
| Kansas AAP | 4535.54 | 19.64 | 0 | 0 | 0.8871 | 79-86 |
| Lake City AAP | 24319.56 | 54.80 | 0 | 13.72 | 0.8824 | 80-86 |
| Lone Star AAP | 40905.99 | 85.60 | 0 | 0 | 0.8163 | 84-86 |
| Longhorn AAP | -43584.51 | 42.83 | 0 | 82.45 | 0.8602 | 84-86 |
| Louisiana AAP | -11929.75 | 47.66 | 0 | 34.53 | 0.7723 | 77-86 |
| McAlester AAP | 7834.18 | 50.57 | 0 | 0 | 0.8231 | 75-86 |
| Milan AAP | 8863.24 | 47.92 | 0 | 0 | 0.9354 | 80-86 |
| Mississippi AAP | 6282.14 | 5.04 | 0 | 29.70 | 0.3929 | 84-86 |
| Newport AAP | 1738.30 | 12.53 | 0 | 0 | 0.9550 | 83-86 |
| Picatinny Arsenal | 73557.11 | 100.97 | 0 | 0 | 0.8702 | 84-86 |
| Pine Bluff Arsenal | 34410.44 | 45.84 | 0 | 0 | 0.6414 | 84-86 |
| Radford AAP | -123120.70 | 188.77 | 0 | 136.96 | 0.8067 | 75-86 |
| Ravenna AAP | 2420.38 | 8.20 | 0 | -2.09 | 0.8947 | 84-86 |
| Riverbank AAP | 11782.02 | 1.15 | 0 | 0 | 0.0032 | 84-86 |
| Rock Island Arsenal | 53759.50 | 69.95 | 0 | 0 | 0.9392 | 82-86 |
| Rocky Mountain Arsenal | 8921.60 | 30.66 | 0 | 0 | 0.7709 | 84-86 |
| Scranton AAP | 36314.49 | 22.13 | 0 | 0 | 0.5322 | 83-86 |
| Sunflower AAP | -158933.59 | 46.51 | 0 | 350.97 | 0.7993 | 82-86 |
| Twin Cities AAP | 10563.38 | 36.41 | 0 | 83.91 | 0.9310 | 75-86 |
| Volunteer AAP | 859.31 | 1.42 | 0 | 0.62 | 0.9309 | 84-86 |
| Watervliet Arsenal | 22436.35 | 42.51 | 0 | 0 | 0.9509 | 84-86 |

*AAP = Army Ammunition Plant.

Table 10

EFAS FY87 Regression Equations--DESCOM Installations

General Equation: $MBtu = B_0 + B_1 \cdot HDD + B_2 \cdot CDD + B_3 \cdot LBRFRC$

| Installation | $B_0$ | $B_1$ | $B_2$ | $B_3$ | $R^2$ | FY Range |
|---|---|---|---|---|---|---|
| Anniston AD* | 35406.44 | 72.64 | 0 | 0 | 0.9253 | 83-86 |
| Corpus Christi AD | 35262.54 | 50.49 | 13.22 | 0 | 0.4280 | 84-86 |
| Fort Wingate DA** | 396.87 | 2.79 | 0 | 0 | 0.6637 | 83-86 |
| Letterkenny AD | 20040.42 | 47.28 | 12.72 | 0 | 0.8894 | 84-86 |
| Lexington-Bluegrass AD | -321.98 | 35.87 | 0 | 4.96 | 0.8786 | 81-86 |
| New Cumberland AD | 14004.74 | 53.01 | 0 | 0 | 0.9459 | 84-86 |
| Pueblo DA | 6750.78 | 20.91 | 0 | 0 | 0.8247 | 84-86 |
| Red River AD | -12578.78 | 87.79 | 0 | 9.29 | 0.9029 | 81-86 |
| Sacramento AD | 11902.24 | 27.85 | 0 | 0 | 0.6358 | 84-86 |
| Savanna DA | 681.27 | 16.94 | 0 | 0 | 0.9740 | 82-86 |
| Seneca AD | 4389.45 | 18.16 | 0 | 0 | 0.9674 | 84-86 |
| Sharpe AD | 15318.90 | 9.22 | 0 | -8.41 | 0.8354 | 83-86 |
| Sierra AD | 3901.85 | 15.23 | 0 | 0 | 0.8910 | 84-86 |
| Tobyhanna AD | 15587.14 | 64.93 | 0 | 0 | 0.9378 | 81-86 |
| Tooele AD | 23701.11 | 58.91 | 0 | 0 | 0.8808 | 84-86 |
| Umatilla DA | 207.82 | 5.68 | 0 | 0 | 0.8737 | 84-86 |

*AD = Army Depot.
**DA = Depot Activity.

Table 11

EFAS FY87 Regression Equations--TECOM Installations

General Equation: $MBtu = B_0 + B_1 \cdot HDD + B_2 \cdot CDD + B_3 \cdot LBRFRC$

| Installation | $B_0$ | $B_1$ | $B_2$ | $B_3$ | $R^2$ | FY Range |
|---|---|---|---|---|---|---|
| Aberdeen PG* | 112958.10 | 259.65 | 0 | 0 | 0.9746 | 84-86 |
| Dugway PG | 12350.00 | 24.80 | 0 | 0 | 0.8623 | 84-86 |
| Jefferson PG | 2409.71 | 7.37 | -2.48 | 0 | 0.7392 | 81-86 |
| White Sands MR** | 38413.55 | 61.44 | 0 | 0 | 0.9346 | 83-86 |
| Yuma PG | 9005.48 | 13.49 | 6.28 | 0 | 0.5086 | 84-86 |

*PG = Proving Ground.
**MR = Missile Range.

Table 12

EFAS FY87 Regression Equations—Other Installations

General Equation: $MBtu = B_0 + B_1 \cdot HDD + B_2 \cdot CDD + B_3 \cdot LBRFRC$

| Installation | $B_0$ | $B_1$ | $B_2$ | $B_3$ | $R^2$ | FY Range |
|---|---|---|---|---|---|---|
| Detroit Arsenal | 39021.48 | 65.66 | 0 | 0 | 0.8950 | 84-86 |
| Fort Monmouth | 43673.79 | 84.04 | 0 | 0 | 0.9115 | 84-86 |
| Harry Diamond Labs | 16827.36 | 11.69 | 0 | 0 | 0.8566 | 83-86 |
| Lima Army Tank Plant | 7015.67 | 28.52 | 0 | 6.43 | 0.8440 | 84-86 |
| Materials Technology Lab | 2657.44 | 18.19 | 0 | 0 | 0.8535 | 84-86 |
| Natick RD&E Center | 8561.44 | 7.48 | 0 | 0 | 0.8569 | 84-86 |
| Pontiac Storage Activity | 299.28 | 1.35 | 0 | 0 | 0.0006 | 83-86 |
| Redstone Arsenal | 169432.50 | 206.78 | 0 | 0 | 0.7991 | 81-86 |
| St. Louis Area Supt Ctr | 5150.97 | 21.39 | 0 | 0 | 0.7097 | 84-86 |
| Stratford Army Engine Plant | 50086.82 | 27.47 | 0 | 0 | 0.3428 | 81-86 |

# 5 EFAS AS AN ENERGY MANAGEMENT TOOL

## Energy Consumption Goal-Setting and Monitoring

The primary use for EFAS is in energy consumption goal-setting and monitoring. Installation adjusted goals for any given fiscal year characterize the energy consumption pattern through the previous fiscal year. Since the effects of weather and LBRFRC variations have been filtered out through multiple regression analysis, it is expected that actual energy consumption would be slightly less than, or at least no greater than, the adjusted goal values provided no significant change in installation square footage has occurred. This result would indicate a decrease, or in the limit, no change, in the energy consumption pattern consistent with progress toward overall energy reduction goals.

If installation square footage has seen a significant change within the last year, current actual energy consumption should be divided by current fiscal year square footage, and adjusted goals divided by previous fiscal year square footage before the comparisons are made. Any significantly large differences between actual consumption and adjusted goals should raise a flag to the energy manager to investigate the causes for this difference. Occasionally, these differences may occur for a given installation in a given month simply due to inherent inaccuracies in the regression equations. However, statistical theory indicates that the errors associated with regression equations are normally distributed with a mean of zero. Hence, while a large error may be observed for a given installation in a given month, errors associated with the monthly adjusted goals should tend to cancel out as values are summed over time or over installations if no change in consumption pattern occurs. For this reason, differences between actual consumption and adjusted goals for a given installation on an annual basis, or for an aggregate of installations (e.g., a large MSC) on a monthly basis, would most likely indicate actual changes in energy consumption patterns.

## Building Energy Glide Path Determination

Building energy reduction goals call for a decline in existing building energy consumption (Btu per square foot) of 8 percent by FY95 using FY85 as the base year. An initial glide path for use in energy management could be formed by assuming an annual energy reduction of 0.8 percent of the FY85 building energy consumption each year. Subsequent actual building energy consumption values could then be compared with the glide path values for evaluating progress toward goal attainment. This approach, however, would not be useful in evaluating the effectiveness of energy conservation efforts because it does not take into consideration differences in energy consumption due to varying weather and production levels between current and base fiscal years.

A much more reasonable approach from the standpoint of energy management would be to establish the glide path based on an annual reduction of 0.8 percent in energy consumption pattern. The annual energy consumption goals would be the same as in the previous case, but the actual energy consumption values would be adjusted to account for differences in weather and production levels between current and base fiscal years prior to comparison with glide path values. This section describes how EFAS can be used to make these adjustments in actual energy consumption for glide path comparisons. A sample calculation is then presented.

Energy consumption adjusted goals for any month of the current fiscal year can be expressed as:

$$[\mathrm{MBtu}]_{CY} = (B_0)_{CY} + (B_1)_{CY} \cdot (\mathrm{HDD})_{CY} + (B_2)_{CY} \cdot (\mathrm{CDD})_{CY} + (B_3)_{CY} \cdot (\mathrm{LBRFRC})_{CY} \qquad \text{[Eq 8]}$$

where the subscript "CY" indicates values for the current fiscal year. An equivalent FY85 energy consumption adjusted goal ($[\mathrm{MBtu}]_{EQ}$) can be defined as:

$$[\mathrm{MBtu}]_{EQ} = (B_0)_{CY} + (B_1)_{CY} \cdot (\mathrm{HDD})_{85} + (B_2)_{CY} \cdot (\mathrm{CDD})_{85} + (B_3)_{CY} \cdot (\mathrm{LBRFRC})_{85} \qquad \text{[Eq 9]}$$

where the subscript "85" indicates values for the base year FY85. $[\mathrm{MBtu}]_{EQ}$ represents the energy that would have been consumed in the current year had the weather and production levels been identical to those of FY85. Note that the values of the regression coefficients used in both Equations 8 and 9 correspond to the current fiscal year predictive equation. If process energy is managed separately from building energy, or if it is desired to make adjustments only for weather differences, then $[\mathrm{MBtu}]_{EQ}$ should be calculated as:

$$[\mathrm{MBtu}]_{EQ} = (B_0)_{CY} + (B_1)_{CY} \cdot (\mathrm{HDD})_{85} + (B_2)_{CY} \cdot (\mathrm{CDD})_{85} + (B_3)_{CY} \cdot (\mathrm{LBRFRC})_{CY} \qquad \text{[Eq 10]}$$

An adjustment factor ([AF]) can be defined as:

$$[\mathrm{AF}] = [\mathrm{MBtu}]_{EQ} \,/\, [\mathrm{MBtu}]_{CY} \qquad \text{[Eq 11]}$$

and a correlation factor [CF] can be defined as:

$$[\mathrm{CF}] = 1 \,/\, [\mathrm{AF}] + (1 - 1 \,/\, [\mathrm{AF}]) \cdot R^2 \qquad \text{[Eq 12]}$$

where $R^2$ is the correlation coefficient for the current fiscal year. An adjusted energy consumption value ($[\mathrm{ENERGY}]_{ADJ}$) for use in glide path comparison can then be calculated as:

$$[\mathrm{ENERGY}]_{ADJ} = [\mathrm{CF}] \cdot [\mathrm{AF}] \cdot [\mathrm{ENERGY}]_{CY} \qquad \text{[Eq 13]}$$

where $[\mathrm{ENERGY}]_{CY}$ is the actual energy consumption for the current fiscal year. The reason for using the correlation factor in Equation 13 is to compensate for the accuracy

of the regression equation. Its effect is to apply the entire adjustment factor for the case of perfect correlation ($R^2 = 1$) and to decrease the amount of adjustment linearly as $R^2$ decreases. For total lack of correlation ($R^2 = 0$), no adjustment is made. If process energy is managed separately from building energy, it should be subtracted from $[ENERGY]_{ADJ}$ prior to comparison with building energy glide path values.

**Sample Calculation**

Actual energy consumption at Indiana AAP for the base year FY85 was 188,340 MBtu. For FY86, the actual energy consumption was 181,461 MBtu. This figure represents a decrease of 3.65 percent from base year usage. Assuming for this example that no significant changes in square footage occurred between FY85 and FY86, the glide path goal would be an 0.8 percent reduction. The multiple regression predictive equation for Indiana AAP for FY86 was determined by EFAS to be:

$$MBtu = 4340.60 + 37.45 \cdot HDD \qquad [Eq\ 14]$$

with a corresponding correlation coefficient ($R^2$) of 0.9281. This equation indicates that HDD is the only significant independent variable at this installation ($B_2 = B_3 = 0$). The total number of HDDs at Indiana AAP was 4168 during FY85 and 4037 during FY86. Hence, some of the 3.65 percent reduction in energy consumption can be attributed to a decreased number of HDDs, whereas the rest can be attributed to a change in energy consumption pattern. It is the latter quantity that corresponds to the adjusted energy consumption and that should be used for comparison with the glide path value. Monthly values of HDD for FY85 and FY86, along with the corresponding values of $[MBtu]_{EQ}$ and $[MBtu]_{86}$ calculated using Equation 14, are given in Table 13. On an annual basis, the values of $[MBtu]_{EQ}$ and $[MBtu]_{86}$ are 208,179 MBtu and 203,290 MBtu, respectively. The adjustment factor is calculated using Equation 11:

$$[AF] = 208179 / 203290 = 1.024$$

The correlation factor is calculated using Equation 12:

$$[CF] = 1 / 1.024 + (1 - 1 / 1.024) \cdot 0.9281 = 0.998$$

The adjusted energy consumption is calculated using Equation 13:

$$[ENERGY]_{ADJ} = 0.998 \cdot 1.024 \cdot 181461 = 185444 \text{ MBtu}$$

This value indicates a 1.54 percent reduction in energy consumption from base year FY85 attributable to changes in energy consumption pattern (i.e., as a result of energy conservation measures). Most of the original 3.65 percent energy reduction (2.11 percent) is attributable to the difference in the number of HDDs. Figure 2 shows the glide path for Indiana AAP and compares the actual and adjusted energy consumption.

Table 13

Glide Path Comparison Data—Indiana AAP

| Month | FY85 HDD | FY86 HDD | $[MBtu]_{EQ}$ | $[MBtu]_{86}$ |
|---|---|---|---|---|
| OCT | 84 | 160 | 7486 | 10333 |
| NOV | 623 | 347 | 27672 | 17337 |
| DEC | 584 | 1067 | 26211 | 44304 |
| JAN | 1222 | 941 | 50105 | 39585 |
| FEB | 896 | 696 | 37896 | 30409 |
| MAR | 458 | 516 | 21493 | 23667 |
| APR | 180 | 224 | 11082 | 12730 |
| MAY | 52 | 69 | 6288 | 6925 |
| JUN | 16 | 0 | 4940 | 4341 |
| JUL | 0 | 0 | 4341 | 4341 |
| AUG | 0 | 12 | 4341 | 4790 |
| SEP | 53 | 5 | 6325 | 4528 |
| TOTAL | 4168 | 4037 | 208179 | 203290 |

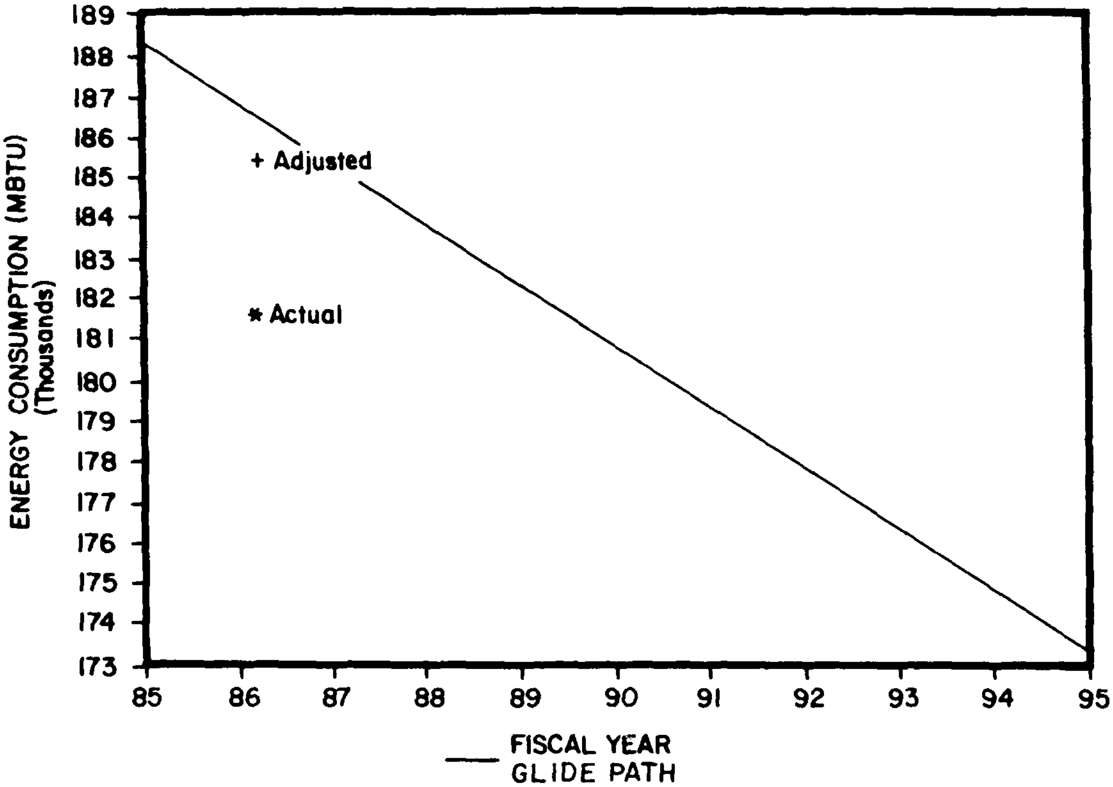


Figure 2. FY86 energy consumption and glide path for Indiana AAP.

# 6 CONCLUSIONS AND RECOMMENDATIONS

USACERL has developed EFAS--an automated tool to help AMC energy managers determine their organization's progress in achieving energy conservation goals. The system uses multiple regression analysis to provide more realistic results than possible using a direct comparison with the base year consumption.

The multiple regression analysis technique has been shown to provide accurate models of energy consumption patterns for most installations within AMC. EFAS uses this technique to provide energy consumption goals that can be compared with actual energy consumption values for energy monitoring and management. EFAS can make energy glide path comparisons on the basis of percentage reduction of energy consumption pattern from the base year. The success of EFAS is evident in the high $R^2$ values obtained during implementation (see the tables).

It is recommended that AMC use EFAS as part of its MACOM-wide energy management program. It is further recommended that: (1) other MACOMs consider developing similar systems for use in their energy management programs, (2) energy consumption goals for the Army be based on reductions in energy consumption pattern rather than actual consumption, and (3) the glide path comparison adjustment technique be allowed to be used for energy consumption reporting to DEIS. The DEIS report currently requires the use of actual consumption data.

Although EFAS is specific for AMC HQ's needs, the multiple regression concept and glide path adjustment technique described in this report are potentially useful in other energy management applications. Development of a system like EFAS for other MACOMS would be site-specific, requiring research to identify the unique independent variables.

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